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WATER ...

and the Land

Facts About Our Water Problem

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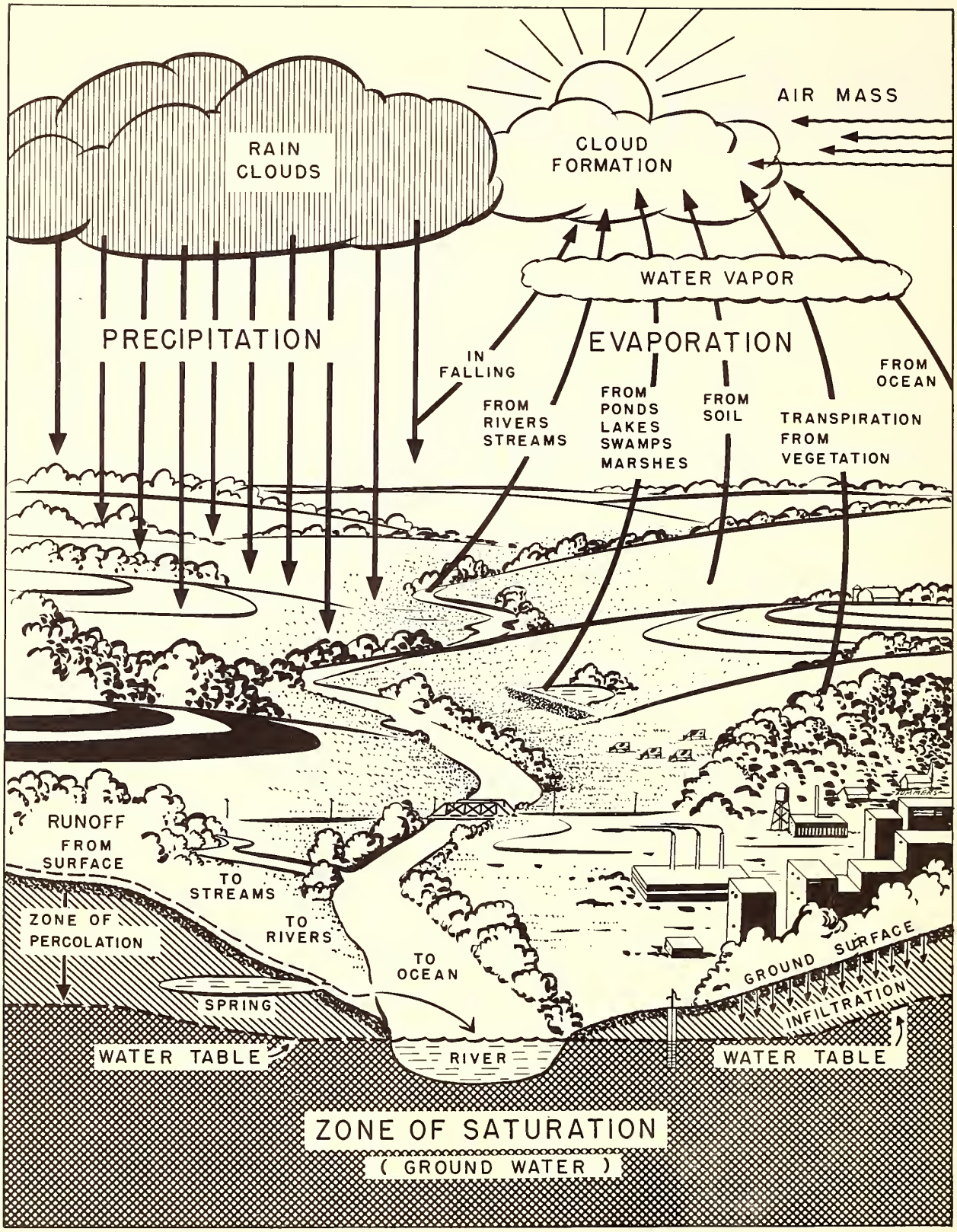
UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service

SCS-TP-134
OCTOBER 1957


AIR MASS
RAIN CLOUDS
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FROM RIVERS STREAMS
FROM PONDS LAKES SWAMPS MARSHES
FROM SOIL
TRANSPIRATION FROM VEGETATION
FROM OCEAN
RUNOFF FROM SURFACE
TO STREAMS
TO RIVERS
TO OCEAN
ZONE OF PERCOLATION
SPRING
WATER TABLE
RIVER
GROUND SURFACE
INFILTRATION
WATER TABLE
ZONE OF SATURATION
(GROUND WATER)

WATER AND THE LAND

By Ben Osborn, Information Specialist, Soil Conservation Service

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THE WATER PROBLEM

The water problem is not one, but many.

There is no national water shortage, but many communities must ration their water supplies.

Every year floods strike scores of communities with disaster. Yet hundreds of arid-land communities would greet a cloudburst as a godsend.

Drought is a recurring hazard in the Great Plains, while drainage is a common problem in the Coastal Plain.

Nearly everywhere there's a water problem--too little or too much, too soon or too late. But each is a local problem, understandable only against the background of local resources, economic development, and needs.

The national aspect of the water problem is the need to conserve and manage the available water resource in each community to best serve the longtime needs of its people.

To understand the problem we need to know some basic facts about water and its use and conservation.

THE WATER SUPPLY

There is just so much water. Except for negligible amounts newly created or destroyed by chemical changes, the earth's water supply remains constant.

But that supply is always on the move. From clouds in the sky to land and ocean, and back to the sky again--it goes round and round in the water cycle, and we use the same water again and again.

The vagaries of its movement through the cycle--uneven distribution and irregular timing--give rise to most problems of local water shortage or excess.

Weather Bureau records show that the average annual precipitation (rain, hail, snow, sleet) in the United States, if spread evenly over the surface, would be about 30 inches. This amounts to about 4,300 billion gallons a day. That is our total water supply.

United States Geological Survey data show that total streamflow derived from surface runoff and ground water amounts to about 8.5 inches a year, or about 1,200 billion gallons a day on the average (17).[1] That is the potential sustained supply for direct human use in homes, industries, irrigation, recreation, etc. It is about 6 times the average daily use now, 4 times the predicted requirements in 1975.

The difference between precipitation and streamflow is the amount returned to the atmosphere as vapor by evaporation and transpiration. That is 21.5 inches a year or 3,100 billion gallons a day, roughly 70 percent of the total water supply. It includes the water used to grow crops, pastures, forests, and all the other vegetation that covers the land.

The water cycle

Precipitation is the source of our water supply.

As water falls upon the earth, part evaporates and part enters the soil. If it falls faster than the soil can take it in, the excess runs off over the surface into streams and eventually to lakes or the sea.

Of the water that enters the ground, most is held in the soil and is used by plants or is evaporated. In either event, it returns to the atmosphere as vapor.

Part passes downward to the ground-water reservoir. When storage spaces are filled, the excess moves laterally and comes to the surface as springs or seeps or augments streamflow.

Thus, in time, practically all water not evaporated from inland surfaces reaches the oceans. Here it passes again into the atmosphere, is carried inland by the winds, forms clouds, and falls as rain, snow, hail, or sleet. This completes the water cycle.

Water and land

Since lakes and streams occupy less than 2 percent of the country's area, about 98 percent of the precipitation must fall on land surfaces.

Whether the water enters the ground or runs off overland depends largely upon the nature and condition of the soil and its vegetative cover.

Also, the capacity of the soil to store water within reach of plant roots varies with soil type and condition.

What happens to the 4,300 billion gallons a day of precipitation that must replenish our water supply is greatly influenced by the management of watershed lands.

Water, therefore, is essentially an agricultural resource. The farmers and ranchers who control our farmlands, rangelands, and woodlands

[1] Numbers appearing in parentheses refer to Literature Cited, p. 13.

also control to an important degree the movement of the water that falls on their land.

USE OF WATER BY PLANTS

Plants take their share of water as it comes to us in the water cycle even before man and animals have an opportunity to use it for drinking.

Water is essential to photosynthesis, by which plants make food that supports all animal life. This is one of the most important uses of water.

About 70 percent of the water reaching the land surface, or 3,100 billion gallons daily, is transpired in the growth of plants or evaporated directly from the soil and other surfaces. How much of this combined requirement, called "evapotranspiration," actually passes through the plants is not known.

But plant growth consumes tremendous amounts of water. A growing tree is at least 50 percent water. Succulent plants like cabbage or lettuce are more than 80 percent water.

The amount of water used by a plant varies widely with the kind of plant and with variations in weather, availability of moisture, and other conditions. At Manhattan, Kans., in one study, single plants of different species used amounts of water ranging from 31 to 140 gallons each during the growing season (18), as follows:

	Gallons
Corn	54
Cowpea	13
Potato (1 hill)	25
Sunflower	130
Ragweed, giant	140
Tomato (pruned to 1 stem)	35
Winter wheat	25

At 54 gallons per plant, an acre of corn at ordinary spacing would transpire 11 inches of water in a season. Additional water would be evaporated directly from the soil. Total water requirement for irrigating corn ranges from 19 to 29 inches in different parts of the country (see Irrigation).

Another measure of the water requirement of plants is the pounds of water transpired per pound of dry matter produced. Table 1 gives examples from studies at Akron, Colo., for the 7 years 1911-17 (28).

Available moisture limits plant growth in many parts of the United States. Successful farming and ranching depend upon catching and holding in the soil as much water as possible for crop and forage production.

WATER FOR HUMAN USE

Although there is plenty of water in the aggregate, one-fourth of the population today faces a problem of water shortage, poor quality, or both. And the prospects are for even more difficulty in the future.

TABLE 1.--Water transpired per pound of dry matter produced, 1911-17, Akron, Colo.

Kind of plant	Pounds of water used--		
	Per pound of dry matter except roots		Per pound of grain
	Low High	Average	Average
Crops:	*Pounds*	*Pounds*	*Pounds*
Alfalfa	482-1,168	844	
Clover, crimson	490-805	636	1,583
Clover, sweet	574-913	731	
Corn	212-516	349	1,405
Cotton	443-657	568	
Cowpeas	413-767	569	1,632
Sorghum, grain	282-356	304	868
Wheat	369-869	557	1,872
Grasses:			
Brome, smooth	752-1,192	977	
Buffalograss	258-346	296	
Grama, blue	290-389	338	
Wheatgrass, western	797-1,263	1,035	
Weeds:			
Buffalobur	413-654	536	
Cocklebur	320-506	415	
Gumweed	450-714	585	

While the potential supply of water after evapotranspiration remains constant, needs for human use pyramid with growing population. Expanding industry and rising standards of living require more water per person to satisfy the American way of life.

From 1900 to 1950, while the United States population doubled, total water use, other than for power, increased fourfold (21).

In 1952 the President's Materials Policy Commission (22, vol. V, p. 93) estimated water needs would double again by 1975, while the population increases 40 percent.

A United States Geological Survey report (17) shows water use in 1955 was up 21 percent from 1950, confirming the Commission's prediction.

Average daily use for all purposes increased from 600 gallons per capita in 1900 to 1,100 gallons in 1950 and 1,300 in 1955. By 1975 the country will be using 1,800 gallons of water a day for every man, woman, and child.

The trend in water use is shown by the estimates of withdrawals for major uses in billions of gallons per day (bgd) in table 2:

TABLE 2.--Trend in water uses

Withdrawal uses	1950[1]	1955[2]		1975[3]	
	Withdrawals (bgd)	Withdrawals (bgd)	Percent of 1950	Withdrawals (bgd)	Percent of 1950
Municipal	14	17	121	20	135
Rural	3.6	2.5	69	5	140
Irrigation[4]	79	81	103	110	139
Industry	77	110	143	215	279
Total	173.6	210.5	121	350	202

[1](16). [2](17). [3](22). [4]Delivered to farms.

Withdrawal and consumption

Not all use of water reduces the supply. Some uses, such as recreation and navigation, do not even require that water be taken from lakes, streams, or other storage.

Figures on amounts of water used for different purposes, such as the foregoing, are for "withdrawals." Some water is withdrawn, used, and discharged, only to be withdrawn again. Some water is recirculated and used several times in the same plant before it is discharged. Each time water is taken from a natural source it is counted in withdrawals, on the assumption that duplicate withdrawals are offset by recirculation.

Important withdrawal uses are (1) municipal, (2) rural domestic and stock, (3) irrigation, (4) industrial, and (5) water power. Nonwithdrawal uses include navigation, recreation, waste disposal, and wildlife conservation.

Water is "consumed" when it is incorporated into a product or is evaporated. Most uses are only partly "consumptive." It is estimated that less than half, perhaps about 40 percent, of withdrawn water is consumed (21).

From 60 to 95 percent of municipal water, 90 percent of industrial water, and 30 to 40 percent of irrigation water are returned to surface or underground storage.

Use of water for power is nonconsumptive.

Most nonwithdrawal uses are also nonconsumptive, although there is loss by evaporation from bodies of water provided for these purposes.

Water for cities and towns

Cities and towns are using more water every year. Both the number of people, and the per-capita water requirement, are increasing.

Municipal water systems supplied their customers 14 billion gallons a day in 1950, 17 billion in 1955 (17). This is an increase of 21 percent in 5 years.

The President's Materials Policy Commission in 1952 estimated that by 1975 municipalities would need 20 billion gallons a day, 35 percent more than in 1950 (22, vol. V, p. 94). The 21-percent increase from 1950 to 1955, however, indicates that this estimate may be low.

About three-fourths of this water comes from streams and lakes, about one-fourth from ground water (17).

Municipal water use is largely nonconsumptive. About 90 percent is returned to natural sources (14).

Average per-capita use of municipal water has increased from 95 gallons a day in 1900 to 145 gallons in 1950 and 148 gallons in 1955 (14).

Per-capita use varies widely from one community to another. The Public Health Service found in 1948 that water use per person ranged from 60 gallons a day in towns of 500 population to 150 gallons in cities of 100,000 and more. Some large industrial cities used as much as 300 to 500 gallons per person per day (25).

The 1950 average daily per-capita use of 145 gallons was divided about as follows: Residential, 50 gallons; industrial, 50 gallons; public (fire fighting, street washing, etc.), 10 gallons; commercial, 20 gallons; loss (through leaks, breaks, etc.) 10 gallons; and other, 5 gallons (14).

Improvements in standards of living and increased use of water-connected devices account for much of the upward trend in per-capita use. Fewer than 300,000 air conditioners were sold in 1946; 1,075,000 were sold in 1953. About 2 million washing machines were sold in 1946; about 3 million in 1953. About 100,000 garbage disposers were sold in 1947; 353,000 in 1953 (14).

Water for rural homes and livestock

Water has always been a major item in locating farms and ranches. The pioneer settler cleared his farmstead beside a spring or stream to provide drinking water for his family and livestock. The plainsman depended upon finding water for a well, and in the far West stockmen feuded over the scattered waterholes.

Rural water comes from private sources. There is no record of the amount used, as for municipal systems. The quantity can only be estimated from population figures and average requirements.

On this basis, the United States Geological Survey estimates that in 1955 about 2.5 billion gallons a day was used in rural homes (17). About three-fourths was from wells and springs.

Rural domestic water needs are figured at 50 gallons per person per day in homes with running water, and 10 gallons per day for those without. About 20 percent of the 47 million rural people live in homes with running water.

Livestock water needs are figured at 15 gallons per animal per day for milk cows; 10 gallons for other cattle, horses, and mules; 4 gallons for hogs; 3 gallons for sheep and goats; and 0.2 to 0.4 pint for poultry.

As more and more people live in cities and towns with public water supplies, the amount of water drawn from private sources for rural use declines. Withdrawals for this purpose were 3.6 billion gallons a day in 1950, 2.5 billion in 1955, a decline of 31 percent. Per-capita use in rural areas, on the other hand, is rising as more farm homes acquire modern conveniences.

Most of this water is directly consumed for drinking or cooking or by livestock. Waste is usually exposed to evaporation. Use of water in farm and ranch homes, therefore, is largely consumptive. Probably not more than 30 percent is returned to storage.

Water for irrigation

Irrigation is the Nation's greatest consumptive use of water, although industry exceeds it in volume of withdrawals.

Farmers withdraw for irrigation nearly five times as much water as municipalities and three-fourths as much as industries use. Most irrigation water is evaporated or transpired by crops, whereas municipalities and industries return nearly 90 percent to sources from which it can be used again.

As a result, irrigation probably consumes more than three times as much water as all other uses combined.

In 1955 farmers used an average of 81 billion gallons of irrigation water a day on their crops. This was an increase of 3 percent over the 79 billion gallons a day in 1950 (17).

An additional 29 billion gallons a day withdrawn from streams and reservoirs for irrigation was lost in conveyance canals before reaching the farms. Most of this water undoubtedly returned to streams or ground water.

On-the-farm requirements for irrigation are expected to reach 110 billion gallons a day by 1975, a gain of 39 percent from 1950 (22, vol. V, p. 94).

About 95 percent of the irrigated land, or about 28 million acres, is in the 17 Western States where the climate is dry and crops depend almost altogether on irrigation (37). In these States the irrigated land is only 3.5 percent of the farmland but it produces 35 percent of the value of all crops harvested (12).

An estimate by the National Resources Board in 1934 placed the total ultimate acreage that could be irrigated in the 17 Western States at 51.5 million acres (30). But not more than 6 million acres of additional land is expected to be put under irrigation by 1975 (22, vol. V, p. 85; 23, vol. I, p. 162).

Irrigation is spreading in the humid East. In 1954 more than 1/2 million acres was irrigated in 28 Eastern States (37). Another million acres, mostly of rice, was irrigated in Arkansas, Louisiana, and Florida (32).

The amount of water needed to irrigate a crop varies with the kind of crop, the location, climate, current weather conditions, and many other factors. Seasonal water requirements for some crops in the West are as follows: Alfalfa, 22 to 52 inches; corn, 19 to 29 inches; cotton, 24 to 31 inches; grains, 12 to 18 inches; oranges, 18 to 32 inches; and pasture, 19 to 25 inches (4). The amount of effective rainfall at the location reduces the irrigation requirement accordingly.

Rice in Arkansas and Louisiana requires from 18 to 36 inches of water (1). Farmers in humid areas use an average of about 6 inches of water to make up the deficiency in rainfall during dry periods in the summer (16).

Irrigators used 91 million acre-feet of water on about 34 million acres of crops in 1955 (17). If distributed evenly, this would be an average of about 32 inches.

More than 70 percent of this water was from surface sources; about 30 percent from ground water.

Part of irrigation water is lost as evaporation, runoff, or seepage below the root zone. With the usual irrigation system, from 40 to 70 percent of the water distributed is available to the crops (3). By correct design and operation of the systems, this level of efficiency can be raised to 60 to 80 percent (24).

The need for irrigation water is not uniform through the year. Crops must be watered primarily during their season of growth, usually only a few months or even weeks. In humid areas, irrigation is needed only in dry periods during the summer.

This concentration of need for irrigation water often puts a strain on local supplies, even where the total quantity would be adequate if its use could be spread over the entire year.

Water for industry

Water is industry's No. 1 raw material. In 1950 industry used from private sources nearly 120 billion tons of water--almost 50 times the weight of all other industrial materials (22, vol. I, p. 50).

Industrial use of water from private sources in 1950 averaged 77 billion gallons a day. By 1955 it had jumped to 110 billion gallons a day, an increase of 43 percent in 5 years (17).

The President's Materials Policy Commission in 1952 predicted 1975 usage at 215 billion gallons a day, an increase of 270 percent from 1950 (22, vol. I, p. 51, and vol. V, p. 94).

These figures do not include water drawn from public water systems, nor water used to generate power.

More than 90 percent of industrial water comes from surface supplies, the rest from ground water.

About 65 percent of industrial water is used by steam-generated electricity plants, mainly for condenser cooling. The rest is used primarily for manufacturing and processing (17).

The average manufacturing plant uses roughly one-fourth its water for cooling, one-fourth for sanitary and service purposes, one-eighth for boiler-feed, and three-eighths for processing its products (19).

A few large plants use most of the water in manufacturing. Of 3,057 plants surveyed by the National Association of Manufacturers, 163 or 5.4 percent that used more than 10 million gallons a day each accounted for 78.2 percent of daily water intake (19).

Manufacturing uses tremendous volumes of water. As much as 300 pounds of water may be required for each pound of finished product (6).

The amount of water used for any product varies widely, according to the process used, efficiency of the plant, the degree to which water is recirculated, and other factors. In table 3 are ranges reported by individual plants in typical industries (19):

TABLE 3.--Water used in manufacturing

Product	Water used, gallons
Steam-generated electricity, per M kw-hr.	52,000 to 170,000
Refined petroleum (processed crude), per M bbl.	151,000 to 15,000,000
Rayon yarn, per ton	250,000 to 403,974
Woolen cloth, per M yd.	40,000 to 510,000
Rolled steel, per ton	6,000 to 110,000
Paper and pulp, per ton	53,000 to 80,000
Paperboard, per ton	7,692 to 90,000
Cane sugar, per ton	4,000 to 110,000

The trend toward synthetic and more highly refined products, as well as the rapid expansion of industry, calls for increased water supplies. For example, one company reports that making synthetic gasoline takes more than 15 million gallons of water per 1,000 barrels, compared to 1 million gallons of water per 1,000 barrels of refined aviation gasoline.

On the other hand, many plants can reduce their water intake by using other types of cooling systems or by recirculating and reusing water. For example, a carbon black plant in Texas with air-cooling uses only 0.25 gallon of water per pound of carbon black produced; similar water-cooled plants use 4 to 14 gallons per pound. By recirculating its water one oil-refining plant withdraws only 40 million gallons a day to meet a plant requirement of 600 million gallons a day.

Other minimum rates of water use that have been reported (13) include:

	Gallons
Steam-generated electricity, per M kw-hr.	1,320
Refined petroleum, per M bbl.	800
Finished steel, per ton	1,400

The local abundance or scarcity of water and the economics of installing and operating water-conserving equipment largely determine the practices used at each plant.

Availability of adequate water is a deciding factor in the location of new industrial plants. More and more, the location of water supplies guides the industrial development of the country.

Water for power

More water is withdrawn from streams and reservoirs to generate power than for all other uses combined. An average of 1,500 billion gallons a day was withdrawn for waterpower in 1955, more than 7 times as much as for all other purposes (17).

But practically all this water is returned to the streams. Usually its quality is not changed, except for increase in temperature. This use ordinarily does not materially reduce the supply of water for other purposes.

Most of this water is used to generate electricity. Some turns the machinery in small factories and mills.

Use of water for power increased 36 percent from 1950 to 1955 (17). Many new hydroelectric plants are being constructed.

Suitable dam sites as well as the quantity of water limit the potentials for using water power. Estimates by the Federal Power Commission in 1951 indicated that at that time the existing plants had a generating capacity of about 18 percent of the potential for the Nation's streams (7).

Water for recreation and wildlife

Water is the key element in many kinds of recreation. It is indispensable to wildlife, which itself is valuable to recreation.

Water is neither withdrawn nor consumed for recreational and wildlife uses, although some is lost to evaporation and seepage. But the withdrawal and consumptive uses, such as irrigation and industry, often reduce the supply or diminish the value of water for recreation and wildlife.

These conflicts pose water problems of increasing importance as population grows and more people live in cities and have more leisure time.

Swimming, boating, fishing, and certain kinds of hunting that depend on suitable bodies of water are among the more popular recreational pursuits.

The intensive use of beaches, lakeshores, and parks and forests that contain streams and ponds shows the growing demand for recreational facilities.

In 1955, 50 million people visited national parks and monuments--2-1/2 times the number of visitors in 1940 (40). More than 45 million went to national forests for recreation--a fourfold increase in 20 years (39). That same year 21 million people fished and 12 million hunted (38).

The supply and use of water for recreation and wildlife cannot be measured in gallons, as for withdrawal uses. Rather, the availability and character of lakes, streams, and other bodies of water to meet the needs in each location are the crucial matters.

Recreational waters need to be clean and in pleasant settings. They need to be stable enough to avoid exposing mud flats or leaving boat docks stranded during the season of use.

Conflicts arise from uses that pollute streams, lakes, and coastal waters; that dry up streams and lower lake levels; or that place obstructions like dams in the path of migrating fish.

Wildlife conservation, aside from recreation, involves other water problems. Fish, waterfowl, and many other kinds of wildlife require suitable aquatic habitats for propagation and survival. Destruction and contamination of these habitats by agriculture, industry, and other enterprises threaten the wildlife supply.

There are, for example, more than 74 million acres of wet lands--marshes, sloughs, meadows, ponds, etc., --in the United States that are of value to waterfowl (29).

About 103 million acres have been or are being drained in organized group enterprises (36). How much land is actually drained each year is not known, but some aquatic wildlife habitats inevitably are destroyed.

On the other hand, new reservoirs and ponds each year create water areas that produce fish and waterfowl. The constant extension of deltas and sedimentation along streams and in lakes add to wet lands. Some landowners are deliberately increasing marsh areas to produce wildlife.

Other nonwithdrawal uses

Transportation of bulk freight by water is important to many industries and cities. About 40 billion ton-miles of freight move annually on inland waterways. This figure is increasing as channels are extended and improved; it is expected to exceed 100 billion ton-miles annually by 1975 (23, vol. I, p. 203).

Streams also serve a valuable function in waste disposal. Within limits, they can purify organic wastes and dilute and carry away industrial refuse. Often, however, this use has turned to abuse. Growing cities and industries have overloaded streams with sewage and other wastes and created serious pollution of water supplies.

SOURCES OF WATER

Despite growing water crises, there is no convincing evidence that total precipitation or runoff is either diminishing or increasing (41).

A city water shortage is a problem of demand--usually expanding rapidly--in relation to the local available supply, which may in fact be diminishing.

For the Nation's water supply is not distributed evenly. Neither is its population, industries, or other water-consuming activities.

Precipitation ranges from 120 inches annually along the Northwest coast to less than 5 inches in parts of the arid Southwest.

Annual runoff--a better measure of the water readily available--varies even more widely. It is more than half the precipitation in some humid areas, but less than 5 percent of the scanty rainfall in some arid ones (22, vol. 1, p. 52).

In most places precipitation and runoff vary greatly from month to month. Unless some of the water can be stored in the flush season to be used in the dry, the community faces water scarcity at intervals.

Surface water

Rivers, creeks, lakes, and reservoirs are the major source of available water. They supply about 75 percent of the water used by cities and towns and by farmers for irrigation, 90 percent of the fresh water used by industry, and nearly all of that used for hydroelectric power (17).

Streams.--Land use has greatly changed the flow regimen of many streams. Deforestation, urbanization, bad farming practices, and range abuse decrease insoak during rains. More of the water runs off quickly, causing increased flooding; less enters the ground to sustain plant growth, feed springs, and to contribute to streamflow.

The Soil Conservation Service, Forest Service, and Tennessee Valley Authority have recorded such changes in several watersheds. For example, during the rains that caused the Kansas River flood in 1951, peak runoff from one small farmland watershed near Hastings, Nebr., was twice as great and occurred in half the time as runoff from an adjoining watershed where conservation practices were in effect (2).

And a small watershed at the Coweeta Hydrologic Laboratory in North Carolina had roughly four times as much surface runoff during a particular storm after it was converted to farmland as it had from a similar storm before the forest cover was cleared (15).

Land use changes and cover improvement on two small watersheds in Tennessee reduced flood peaks and sedimentation rates without materially affecting water yields or total evapotranspiration (11).

Total annual streamflow from large river basins seems to be little changed by land use. But the timing, the size of peak flows, and the portions of streamflow derived from surface runoff and from ground water may be greatly altered.

These changes aggravate water shortages during dry seasons and flood hazards during wet ones.

Reservoirs.--Reservoirs store floodwater until it is needed for useful purposes.

Without artificial storage less than half the runoff in humid areas can be depended upon for

regular use. In arid and semiarid areas even less can be beneficially used.

More than 10,000 reservoirs larger than farm ponds have been constructed in the United States (5).

In 1954 there were 1,300 larger than 5,000 acre-feet capacity, with a combined surface area of more than 11 million acres. These larger reservoirs could store 278 million acre-feet of water--more than 20 percent of the annual streamflow (35).

In addition there were countless smaller lakes and ponds. The Soil Conservation Service estimates that farmers and ranchers had built more than 1-1/4 million ponds with Federal assistance by the end of 1955.[2] The average size of these ponds is about 2 acre-feet.

Ground water

Underground reservoirs contain more fresh water than all surface reservoirs and lakes combined, including the Great Lakes. Ground water is estimated to equal 10 years' average rainfall or 35 years' average runoff (21).

This water has accumulated through the centuries. Only a small part of it is available for human use. Nevertheless, about one-sixth of all the water used in the United States comes from underground sources.

Ground water is part of the water cycle. Water that soaks into the ground beyond the plant-root zone adds to underground storage. Most underground water moves, though often very slowly, and some is discharged as springs and seeps or subsurface flow in streams.

Variable rock structure causes underground water to be very unevenly distributed. In less than half the United States can wells be made to yield enough water for irrigation, industrial, or municipal use. The United States Geological Survey has mapped the principal ground-water reservoirs of the United States (33, 34).

In many areas ground water is being used faster than it is naturally replenished through the water cycle. In effect, the stored water is being "mined;" water levels in wells are dropping, and the irrigation projects, municipalities, and industries depending on them are threatened.

For example, in the southern High Plains, the rate of pumping is 30 to 50 times the estimated recharge. In the Chicago area pumping for city water supply has lowered artesian pressure by more than 400 feet (33).

In many coastal areas salt water is replacing fresh water where overpumping has lowered water tables to below sea level. In oil fields salt water from lower levels often contaminates fresh-water supplies. These and other types of salt-water intrusion are making serious inroads on useful ground-water supplies (20).

WATER LOSSES

Local water shortages arise in part from losses that keep some of the potential supply from being put to beneficial use.

Flash runoff robs communities of part of their natural water resource. Peak flows that exceed storage facilities are an economic loss, aside from the damage they do as floods.

Sedimentation that reduces storage capacity, evaporation that dissipates stored water, and pollution that makes water unfit for certain uses all reduce the usable supply.

Sedimentation

Sediment carried into ponds and reservoirs by flowing water gradually fills their storage basins. In 1950 the average loss to the Nation's reservoirs was estimated at 350,000 acre-feet annually (5).

Individual reservoirs commonly lose from a fraction of 1 percent to more than 3 percent of their storage capacity annually. Ponds may fill up more rapidly.

Reservoirs lose most of their value when they are 50 to 80 percent silted. Their useful life, therefore, may be as little as 15 or 20 years where sedimentation rates are highest and storage capacity is small, as with farm ponds receiving runoff from unprotected cultivated land.

On the other hand, large reservoirs in forested areas or with otherwise well-protected watersheds may be useful for 200 to 300 years or more at present rates of sedimentation.

Sediment also fills harbors, canals, and rivers, where it interferes with navigation. More sediment is dredged from rivers and harbors each year than the volume of earth excavated from the entire Panama Canal (5).

Sediment in the water adds $5 million annually to the cost of filtering public water supplies (27). It detracts from the value of water for recreation and fish life.

Sedimentation is most serious in watersheds with much unprotected land where erosion is active.

Evaporation and transpiration

Evaporation from surface reservoirs is a loss that cannot be avoided, but sometimes might be reduced.

Normal evaporation from the 11-million-acre surface of the Nation's major reservoirs exceeds the quantity withdrawn for public supplies. Evaporation from farm ponds is more than the water used for rural homes and livestock (17).

[2] SCS and ACPS records.

Evaporation from reservoirs can be held to a minimum by good design that results in small surface area in relation to storage capacity. Tree and shrub windbreaks sometimes can reduce evaporation from small ponds. Experiments with chemicals that form a thin film on the water surface offer hope of another way to reduce evaporation (8).

Transpiration from plants that grow with their roots in the water table, called phreatophytes, withdraws much water from reservoirs, streams, and irrigation canals. These plants occupy an estimated 15 million acres in the West. They consume 20 to 25 billion gallons of water a day (22, vol. V, p. 96).

Transpiration from crops, forests, range, and wildlife and watershed cover, on the other hand, is not a water loss. The growth of beneficial plants is perhaps the most important use of water.

Pollution

Pollution of streams, lakes, and coastal waters with sewage and other wastes from cities and industries reduces the supply of water suitable for many uses.

A pollution survey in 1950 revealed that 11,800 municipal sewer systems and 10,400 independent factory-waste outlets were discharging into public waters (26).

Only 6,700 of the sewage plants and 2,600 of the industrial plants gave adequate treatment to the wastes.

More than 2,000 industries discharged inorganic wastes, such as acids and poisonous chemicals. In addition, drainage from abandoned coal mines poured 10,000 tons of acid pollution into waterways daily.

Thus, although cities and industries return nearly 90 percent of the water they use to natural sources, some of the water may be largely worthless for reuse.

In many places, pollution has made water unfit for swimming and other recreational uses. Desirable fish do not thrive in polluted waters.

Pollution can be controlled. Several States have pollution abatement programs that have made dramatic improvements in important rivers. The Federal Water Pollution Control Act of 1948 provides for Federal assistance in these programs.

PROBLEMS OF TOO MUCH WATER

Too much water at the wrong time may be as serious as too little. Many communities must cope with recurring floods. Much good land was originally too wet for agricultural use and had to be drained.

Floods

Hardly a year goes by without a disastrous flood somewhere in the United States.

The Columbia River flood of 1948 made 60,000 persons homeless and caused property damage estimated at $200 million. Damage by a flood on the Kansas River in 1951 was estimated at $800 million to $1 billion.

Less spectacular are the many floods that occur every year on the smaller tributaries of the great rivers. These smaller floods cause even more total damage than the big ones.

The average annual damage from floods in the United States is about $1 billion. About 56 percent of this occurs on the upstream tributaries and 44 percent in the downstream valleys (10).

Most of the damage on the headwater streams results from floods that occur oftener than once in 10 years. Most of this damage--about 70 percent--is agricultural.

Most of the downstream flood damage is to residences, industrial property, and transportation facilities. These damages continue to rise from year to year because of increasing value of property concentrated in flood plains. Even so, about a third of the damage in large valleys is to rich agricultural land in the flood plains.

Floods can be reduced by soil and water conservation on the farmlands, forests, and ranges that make up the watersheds and by water-control structures on the upstream channels.

Floods can be further controlled by large downstream dams, dikes, and other structures to protect cities and towns, urban property, and agricultural land on the downstream flood plains.

Both upstream and downstream measures are encouraged by the Federal Government.

Drainage

Drainage of wet land has been a necessary step in much of the settlement and agricultural development of America.

Nearly a fourth, or about 216 million acres, of the Nation's potential agricultural land was originally too wet for farming (9).

Even urban development has depended upon drainage. Many town sites in the eastern and coastal areas had to be drained. Central Park in New York City was drained in 1858.

The 1950 Agricultural Census showed 103 million acres in organized drainage enterprises (36) of which about 82 million acres has been improved (42). This included extensive areas of flat fertile land in the humid States that proved to be among our most productive cropland.

The acreage drained by individual farmers outside organized projects is not known.

There remains about 120 million acres of wet land in the United States. This includes about 30

million acres already in cultivated fields that would be suitable for continued use for crops or pasture if properly drained and supplied with community outlets. Another 20 million acres that would require clearing and complete drainage would be suitable for cultivation if required. This leaves about 70 million acres now considered most adaptable to wildlife, recreation, and limited use for timber growing and grazing (31).

Much of the initial drainage work was inadequate by modern standards or has been impaired by deterioration of ditches and outlets.

The Soil Conservation Service in 1955 estimated that about 67 million acres, or nearly a fifth of the present cropland, needs improved drainage.[3] This includes many small areas that can be treated within a single farm.

Much of the land needing drainage for agriculture is not often covered with water. Rather, the soils are waterlogged, excluding air from the root zone and making them unsuitable for growing crops. Or they may be dotted after rains with transitory pools that interfere with land preparation and planting, or drown out patches of crops, then disappear.

Of the 74 million acres of wet lands inventoried by the Fish and Wildlife Service in 1954, 35 million or nearly one-half were subject to only seasonal flooding (29).

Naturally, the best and most easily improved land was drained first. Nevertheless, some land drained for agricultural purposes was later found to be unsuitable for crop or pasture production.

New drainage work needs to be carefully planned within the known capabilities of the land. Wildlife and recreational values also need to be safeguarded.

WATERSHED PROTECTION AND CONSERVATION

Water problems in the last analysis are watershed problems.

A watershed is any area of land that drains into a particular stream or body of water. Small streams, of course, flow into larger ones, so the entire country is a patchwork of small watersheds comprising successively larger ones.

Watershed divides separate the water supply into distinct parts as it comes to us in the water cycle. The character and condition of the land on which water falls influence its movement into or over the ground. Land management, therefore, affects the timing of the water's arrival to streams, lakes, or underground reservoirs from which it can be withdrawn for human use.

The people in each watershed have their own water resource with which to meet their own needs. It is within these confines that problems of water shortage, flooding, or pollution arise.

[3] Unpublished reports, SCS-199 for calendar year 1955.

And it is within separate watersheds that communities can manage their water resource to best meet their own needs.

Small watershed projects

Solution of the water problems in a watershed takes teamwork.

All the people must plan and act together to make the best use of all their land and water resources.

Water control and conservation cannot be separated from soil conservation. Urban and industrial uses also make demands on the water supply, and affect its quality, so that city people as well as farmers must take part in watershed projects.

Farmers across the Nation are attacking water problems where they begin--on the land. Soil conservation districts include nearly 90 percent of all agricultural land. Through these locally managed districts, farmers and ranchers are putting basic soil and water conservation plans into effect on their own land.

At the same time, rural and urban interests all over the country are joining forces in small watershed protection and flood prevention projects that deal with all aspects of land and water conservation.

This teamwork on the part of local people is matched by teamwork among governmental units. Local, State, and Federal agencies cooperate in planning, financing, and carrying out projects under the Watershed Protection and Flood Prevention Act (Public Law 566, 83d. Cong., as amended by Public Law 1018, 84th Cong.).

These projects combine soil and water conservation on the land with control and use of runoff by means of upstream structures in small watersheds. Land treatment to increase vegetation, improve soil condition, and retard surface runoff precedes structural work on the streams.

The Federal Government, through the United States Department of Agriculture, provides technical and financial assistance of three kinds: (1) Technical assistance in planning, designing, and installing works of improvement; (2) sharing costs of flood-prevention and agricultural water management; and (3) long-term credit to help local interests with their share of the costs.

Structural measures can be of three kinds: (1) Flood-prevention measures, which are eligible for Federal assistance up to the full cost of construction; (2) agricultural water-management measures, such as drainage and irrigation or provision of a more uniform water supply for agricultural use, which are eligible for Federal technical assistance and cost-sharing; and (3) nonagricultural water-management measures, such as municipal or industrial water supplies, streamflow regulation, or wildlife and recreational facilities, for which local interests bear the full cost.

Small watershed projects are initiated by local organizations, such as soil conservation districts, municipalities, counties, or watershed associations.

The Soil Conservation Service has administrative leadership for the United States Department of Agriculture's part in these projects. Upon request SCS will supply information about the Watershed Protection and Flood Prevention Act.

In small watershed projects, the activities of all agencies dealing with water control and management can be correlated. These might include downstream flood-control work by the Corps of Engineers, reservoirs and irrigation projects by the Bureau of Reclamation, wildlife-habitat development by the Fish and Wildlife Service, pollution abatement by the Public Health Service, and development of municipal and industrial water supplies.

WATER RIGHTS

In pioneer days the needs for water in the humid East were greatly exceeded by the supply. A person's right to use water where he found it was taken for granted, like his right to breathe the air.

As more people sought to use watercourses, conflicts were settled by the riparian principle; i.e., that owners of land touching the same stream have equal rights to use it. Legal rights to water were based on common law or court decisions.

In the arid West, on the other hand, settlers from the first competed for the scarce water supply. Legal rights were defined early by legislative acts that provided for specific appropriation of water for beneficial uses.

Now in all States competition for available water raises many questions of water rights.

When a farmer uses a stream to irrigate, a city builds a dam for storage, or a county diverts runoff to protect a road, questions of legal rights are involved.

In general, any activity relating to storing, retarding, diverting, discharging, collecting, pumping, or otherwise artificially affecting the use of water or the damage caused by it may concern water rights.

The rather indefinite rights based on common law and the riparian principle are a poor safeguard for expensive investments often required for water conservation and management.

Most of the Eastern States and some of the Western ones, therefore, are taking steps to study their water problems and modernize their water laws.

In small watershed projects and in assistance to soil conservation districts, the United States Department of Agriculture abides by the water laws in each State. The landowners and local people concerned in each project are responsible for obtaining the necessary water rights.

SOME MEASURES OF WATER

1 gallon is 231 cubic inches, 0.1337 cubic feet.
1 cubic foot is 7.48 gallons.
1 gallon weighs 8.34 pounds.
1 cubic foot weighs 62.4 pounds.
1 acre-inch is 27,154 gallons or 3,630 cubic feet.
1 acre-foot is 325,851 gallons or 43,560 cubic feet.
1 cubic foot per second is 448.8 gallons per minute or 646,317 gallons per day.

LITERATURE CITED

(1) Adair, C. R., and Engler, K.
1955. The irrigation and culture of rice. U. S. Dept. Agr. Yearbook. pp. 389-394.

(2) Allis, J. A.
1952. The story of two watersheds. Jour. Soil and Water Conserv. 7: 243-245.

(3) Blaney, H. F.
1955. Climate as an index of irrigation needs. U. S. Dept. Agr. Yearbook. pp. 341-345.

(4) _____, and Criddle, W. D.
1950. Determining water requirements in irrigated areas from climatological and irrigation data. U. S. Dept. Agr. Soil Conserv. Serv. SCS-TP-96. 48 pp., illus.

(5) Brown, C. B.
1951. Sediment steals water storage. Jour. Soil and Water Conserv. 6: 92-98.

(6) Chemical Engineering.
1949. The water problem. Chem. Engr. 56: 119-126.

(7) De Luccia, E. R., and Weaver, F. L.
1952. Status of hydroelectric power development in the United States. In The physical and economic foundation of natural resources. II. The physical basis of water supply and its principal uses. House Interior and Insular Affairs Comm. pp. 67-74.

(8) Dixey, F.
1956. Variability and predictability of water supply. In The future of arid lands. Amer. Assoc. Adv. Sci. Pub. 43. pp. 121-140.

(9) Erickson, F., Abrams, W., Fasken, G., Beauchamp, K., and Barnes, B.
1955. The Nation's water resource problems. Jour. Soil and Water Conserv. 10: 197-200.

(10) Ford, E. C., Cowan, W. L., and Holtan, H. N.
1955. Floods--and a program to alleviate them. U. S. Dept. Agr. Yearbook. pp. 171-176.

(11) Frye, A. S.
1957. Effects of major river basin development on watershed improvement. Jour. Soil and Water Conserv. 12: 65-70.

(12) Greenshields, E. L.
1955. The expansion of irrigation in the West. U. S. Dept. Agr. Yearbook. pp. 247-251.

(13) Hudson, H. E., Jr., and Abu-Lughod, J.
1956. Water requirements. In Water for industry, pp. 12-22. Ed. by J. B. Graham and M. F. Burrill. Amer. Assoc. Adv. Sci. Pub. 45.

(14) Jordan, H. E.
1955. The problems that face our cities. U. S. Dept. Agr. Yearbook. pp. 649-652.

(15) Lassen, L., Lull, H. W., and Frank, B.
1952. Some plant-soil-water relations in watershed management. U. S. Dept. Agr. Cir. 910. 64 pp., illus.

(16) MacKichan, K. A.
1951. Estimated use of water in the United States--1950. U. S. Geol. Surv. Cir. 115. 13 pp., illus.

(17) _____
1957. Estimated use of water in the United States--1955. U. S. Geol. Surv. Cir. 398. 18 pp., illus.

(18) Miller, E. C.
1938. Plant Physiology. 2d ed. New York. 1,201 pp., illus.

(19) National Association of Manufacturers and The Conservation Foundation.
1950. Water in industry. New York. 51 pp.

(20) Parker, G. G.
1955. The encroachment of salt water into fresh. U. S. Dept. Agr. Yearbook. pp. 615-635.

(21) Piper, A. M.
1953. The nation-wide water situation. In The physical and economic foundation of natural resources. IV. Subsurface facilities of water management and patterns of supply--type area studies. House Interior and Insular Affairs Comm. pp. 1-20.

(22) President's Materials Policy Committee.
1952. Resources for freedom. U. S. Govt. Print. Off., 5 vol.

(23) President's Water Resources Policy Commission.
1950. A water policy for the American people. U. S. Govt. Print. Off., 3 vol.

(24) Quackenbush, T. H., Renfro, G. M., Beauchamp, K. H., Lawhon, L. F., and Eley, G. W.
1957. Conservation irrigation in humid areas. U. S. Dept. Agr. Hbk. 107. 52 pp., illus.

(25) Scheele, L. A.
1952. Domestic and industrial uses of water. In The physical and economic foundation of natural resources. II. The physical basis of water supply and its principal uses. House Interior and Insular Affairs Comm. pp. 42-56.

(26) Schwob, C. E.
1955. Pollution--a growing problem of a growing Nation. U. S. Dept. Agr. Yearbook. pp. 636-643.

(27) Shannon, W. G., MacKichan, K. A., Blaney, H. F., Thorne, M. D., and Edminster, T. W.
1955. The Nation's water requirements. Jour. Soil and Water Conserv. 10: 81-84. Mar.

(28) Shantz, H. L., and Piemeisel, L. N.
1927. The water requirement of plants at Akron, Colo. Jour. Agr. Res. 34: 1093-1190.

(29) Shaw, S. P., and Fredine, C. G.
1956. Wetlands of the United States. U. S. Fish and Wildlife Serv. Cir. 39. 67 pp., illus.

(30) Straus, M.
1952. Use of water for irrigation. In The physical and economic foundation of natural resources. II. The physical basis of water supply and its principal uses. House Interior and Insular Affairs Comm. pp. 61-66.

(31) Sutton, J. G.
1954. Drainage in the humid areas of the United States. Proc. Amer. Soc. Civil Engr. 80 (Sep. 460): 1-18.

(32) Tharp, M. M., and Crickman, C. W.
1955. Supplemental irrigation in humid regions. U. S. Dept. Agr. Yearbook. pp. 252-258.

(33) Thomas, H. E.
1952. Ground-water regions of the United States--their storage facilities. In The physical and economic foundation of natural resources. House Interior and Insular Affairs Comm. Vol. III, pp. 3-78.

(34) ————
1955. Underground sources of our water. U. S. Dept. Agr. Yearbook. pp. 63-78.

(35) Thomas, N. O., and Harbeck, G. E., Jr.
1956. Reservoirs in the United States. U. S. Geol. Surv. Water-Supply Paper 1360-A. 99 pp., illus.

(36) U. S. Bureau of Census.
1952. Drainage of agricultural lands. U. S. Census of Agriculture, 1950. Vol. IV. U. S. Dept. Comm. 307 pp.

(37) ————
1956. Irrigation in humid areas. U. S. Dept. Comm. and U. S. Dept. Agr. U. S. Census of Agriculture 1954, Vol. III, Pt. 6: 121 pp., illus.

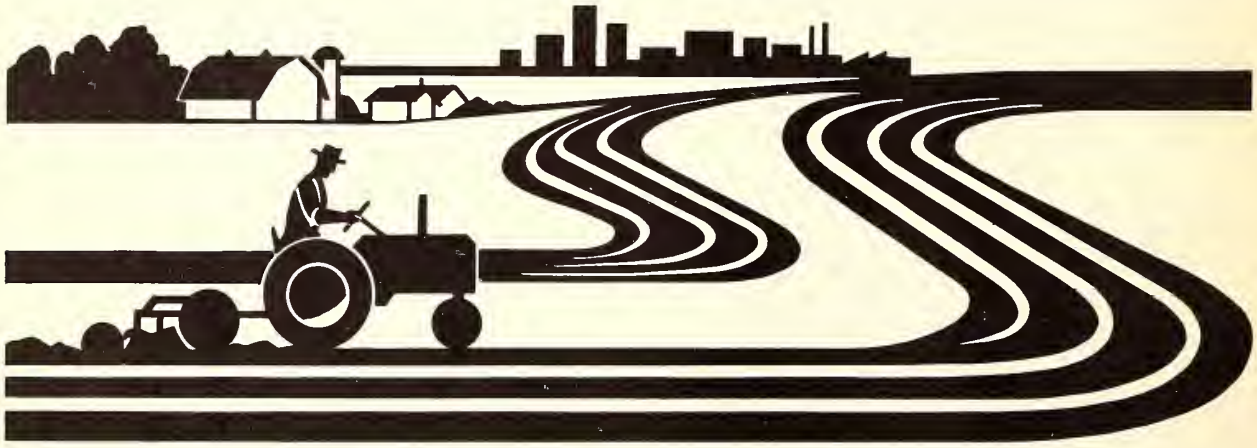
(38) U. S. Fish and Wildlife Service.
1956. National survey of fishing and hunting, 1955. U. S. Fish and Wildlife Serv. Cir. 44. 50 pp., illus.

(39) U. S. Forest Service.
1957. Operation outdoors. Part 1. National forest recreation. U. S. Forest Service. 14 pp. illus.

(40) U. S. National Park Service.
1956. Our heritage, a plan for its protection and use: "Mission 66." U. S. Natl. Park Serv. [Unpaged.]

(41) Wells, J. V. B., and Williams, A. H.
1951. The water situation in the United States. Jour. Soil and Water Conserv. 6: 78-82, 100, 106.

(42) Wooten, H. H.
1953. Major uses of land in the United States. U. S. Dept. Agr. Tech. Bul. 1082. 100 pp., plus supplement of statistical tables, 78 pp.



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